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**Papadourakis**

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(54) **MOTION CAPTURE AND ANALYSIS**

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703/2

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

3,820,133 A 6/1974 Adorney et al.  
3,945,646 A 3/1976 Hammond  
5,056,783 A 10/1991 Matcovich et al.  
5,056,791 A 10/1991 Poillon et al.  
5,062,641 A 11/1991 Poillon et al.  
5,269,519 A 12/1993 Malone  
5,332,225 A 7/1994 Ura

5,447,305 A 9/1995 Socci et al.  
5,688,183 A 11/1997 Sabatino et al.  
5,694,340 A 12/1997 Kim  
5,792,000 A 8/1998 Weber et al.  
5,941,779 A 8/1999 Zeiner-Gundersen  
6,073,086 A 6/2000 Marinelli  
6,173,610 B1 1/2001 Pace  
6,227,984 B1 5/2001 Blankenship

(Continued)

**FOREIGN PATENT DOCUMENTS**

EP 0494749 A1 7/1992  
EP WO9745176 A1 12/1997

(Continued)

**OTHER PUBLICATIONS**

Katynski, Liz; Swinging Jazz man: Terry Hashimoto vs the giants of  
golf (Jazz Golf Equipment Pres. Terry Hashimoto)(Cover Story);  
Manitoba Business; Oct. 1, 1997; 2 pages; <highbeam.com/doc/  
1G1-20242967.html>.

(Continued)

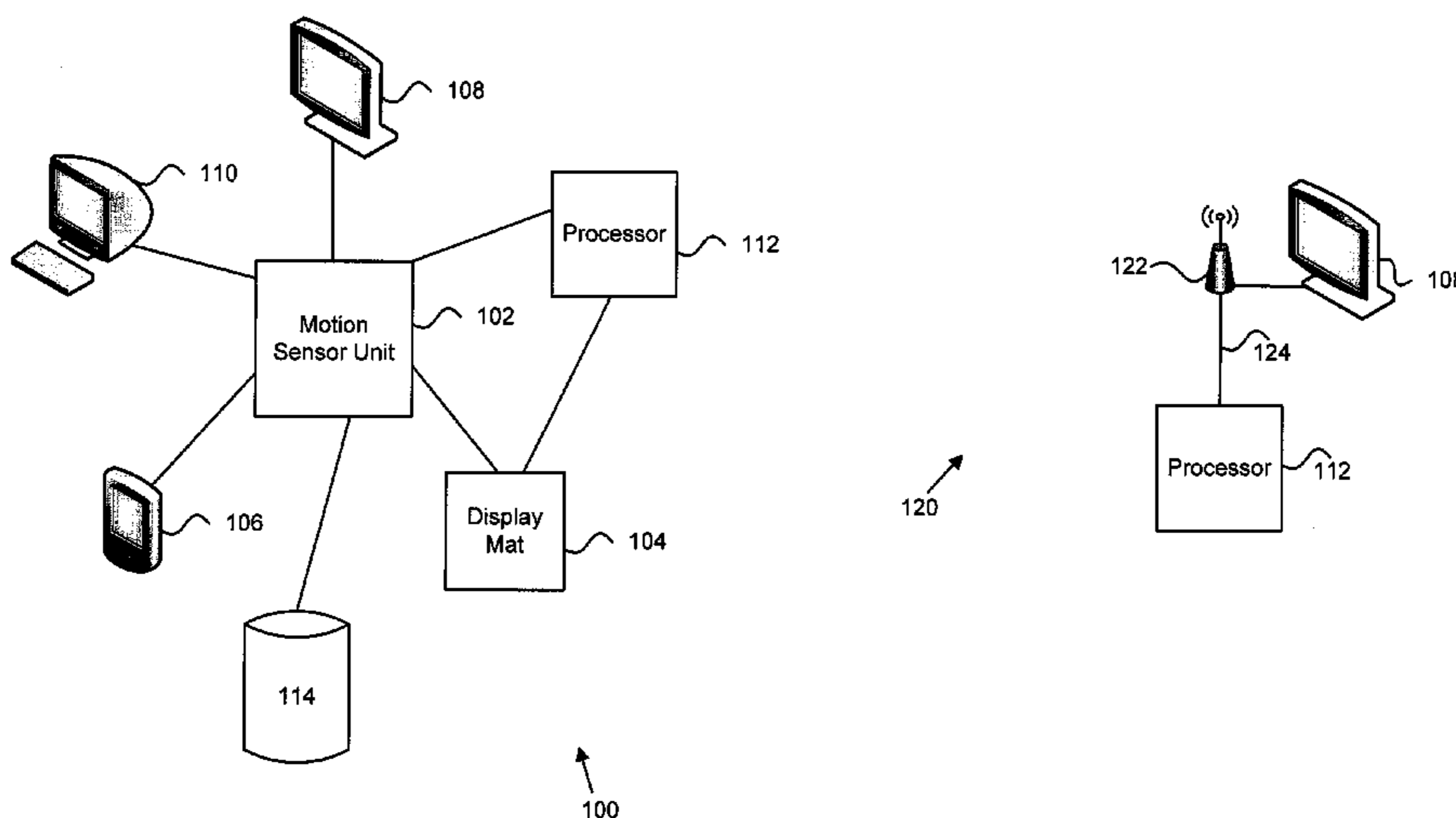
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(57) **ABSTRACT**

Motion capture and analysis is described, including a motion  
sensor unit configured to capture data associated with move-  
ment of an object, to process the data to determine one or  
more values, to store the data and the one or more values, and  
to convert the data and the one or more values from an analog  
signal to a digital signal associated with a wireless transmis-  
sion, and a display unit configured to receive the data from the  
motion sensor unit, the data being transmitted using through  
the wireless transmission, to process the data to determine  
one or more values, to store the data, and to graphically  
present the data and the one or more values.

**24 Claims, 9 Drawing Sheets**



(56)

References Cited

U.S. PATENT DOCUMENTS

6,441,745	B1	8/2002	Gates	
6,607,450	B1	8/2003	Hackman	
6,821,211	B2	11/2004	Often et al.	
7,021,140	B2 *	4/2006	Perkins .....	73/493
7,022,026	B2	4/2006	Blankenship	
7,264,554	B2	9/2007	Bentley	
7,329,193	B2	2/2008	Plank, Jr.	
2001/0017347	A1	8/2001	Blankenship	
2002/0077189	A1	6/2002	Tuer et al.	
2004/0127304	A1	7/2004	Plank, Jr.	
2005/0034511	A1	2/2005	Knecht	
2005/0054456	A1	3/2005	Gobush	
2006/0025229	A1 *	2/2006	Mahajan et al. ....	473/131
2006/0247070	A1	11/2006	Funk et al.	
2007/0135225	A1 *	6/2007	Nieminen et al. ....	473/212
2007/0206837	A1	9/2007	Kirby	
2007/0270214	A1	11/2007	Bentley	
2007/0298896	A1 *	12/2007	Nusbaum et al. ....	473/131

FOREIGN PATENT DOCUMENTS

GB	2318982	A	5/1998
SU	814373		3/1981

WO	91/04769		4/1991
WO	91/06348		5/1991
WO	96/16706		6/1996
WO	WO0069528	A1	11/2000
WO	01/43837		6/2001
WO	WO0235184	A3	5/2002
WO	03/024552		3/2003
WO	2006/081395		8/2006
WO	2007/019441		2/2007
WO	2007/112290		10/2007

OTHER PUBLICATIONS

Kirbyson, Geoff; Golf whiz invents swing-fix device, New high-tech clip shows your technique; Winnipeg Free Press; Mar. 14, 2010; 4 pages; <winnipegfreepress.com>.

Britten, Liam; PocketPro could be the best golf coach you've ever had; Tech Vibes; Jan. 10, 2011; 3 pages; <www.techvibes.com/blog/pocketpro-could-be-the-best-golf-coach-youve-ever-had-2011-01-10>.

Hoffman, Perry J.; Letter to Michael K. Lindsey, entitled "NewSpin Golf, LLC U.S. Patent Appl. 2010/0049468 AP"; Jul. 10, 2013; Northbrook, IL US; 11 pages.

\* cited by examiner

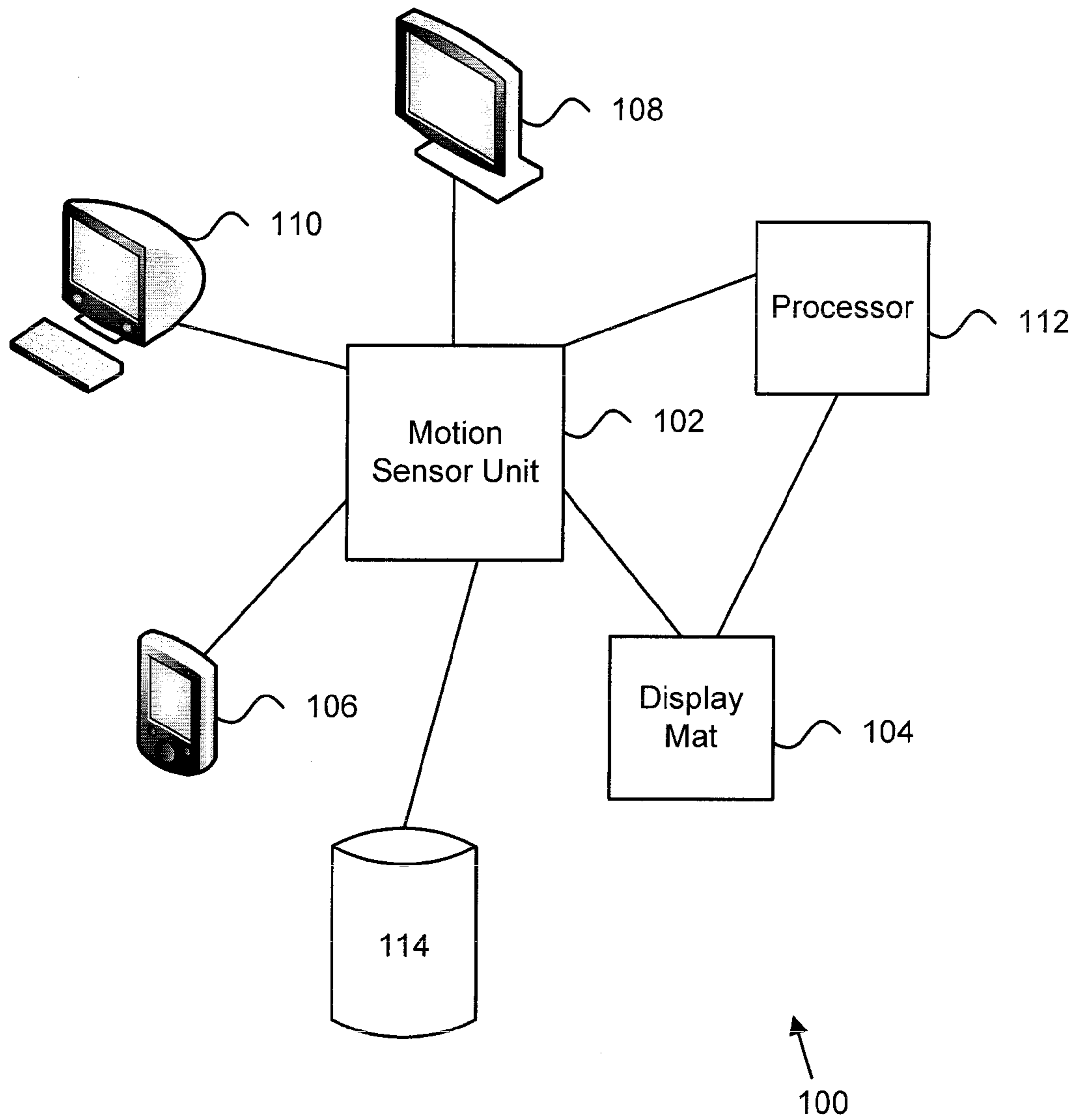


FIG. 1A

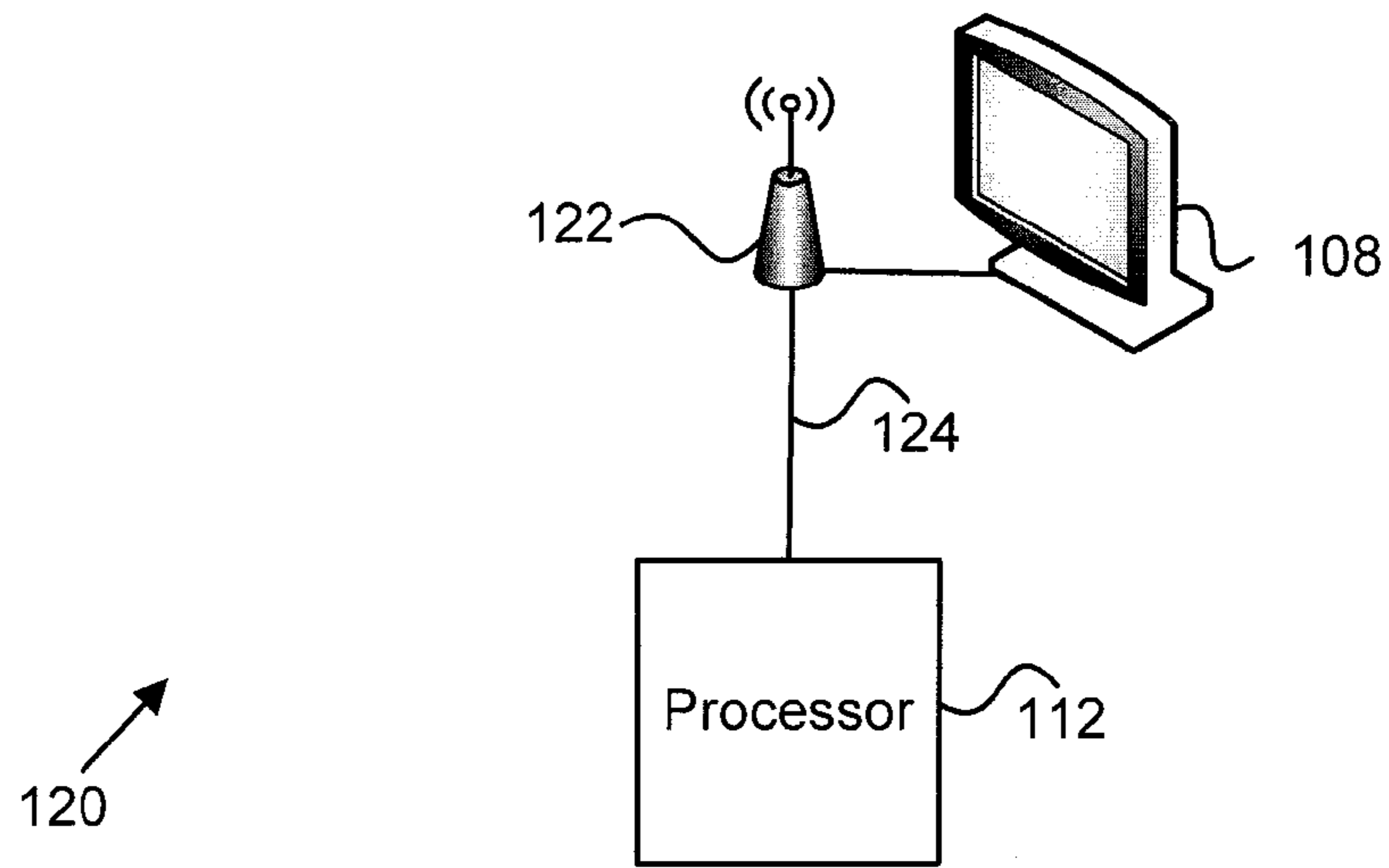


FIG. 1B

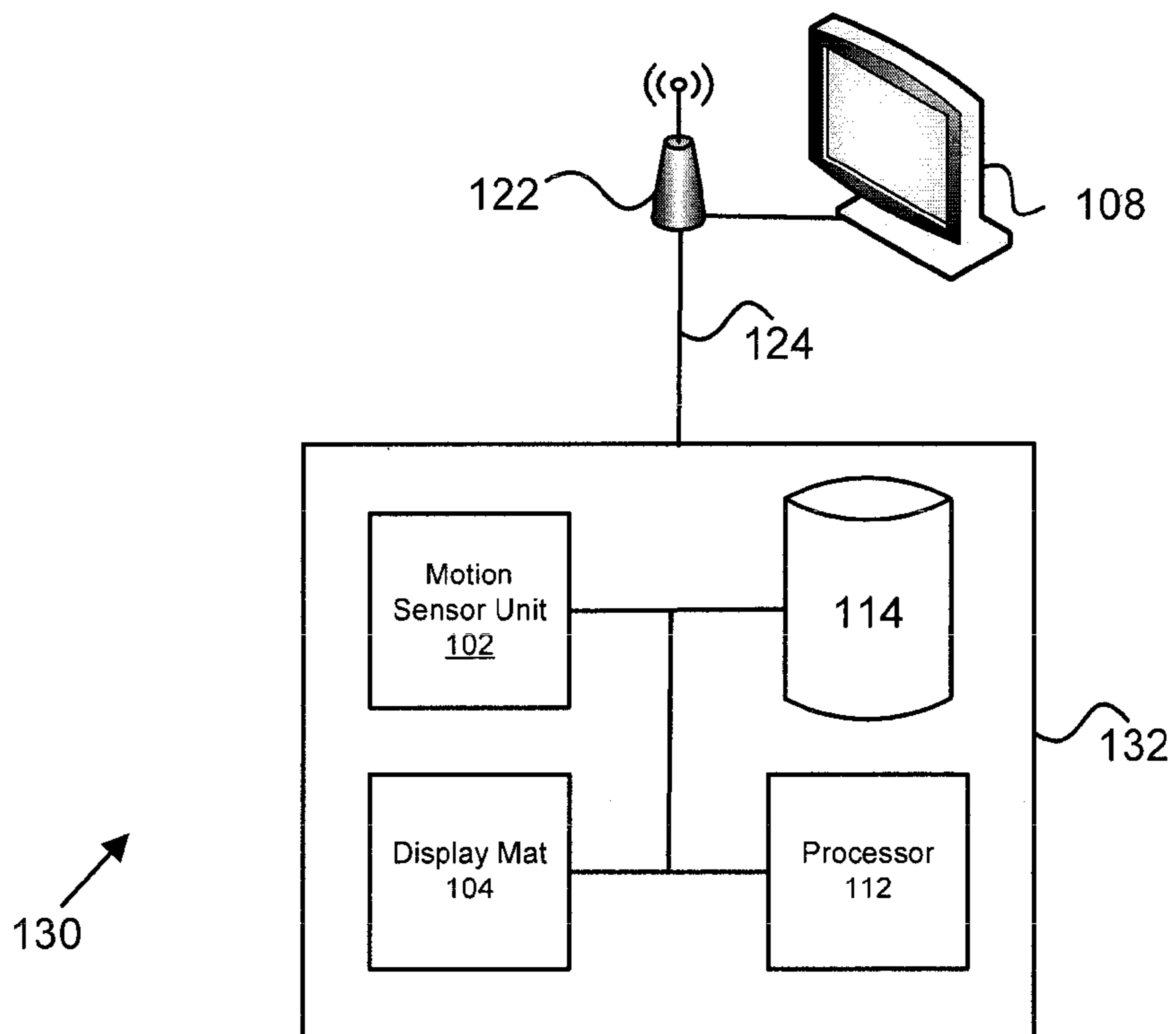


FIG. 1C

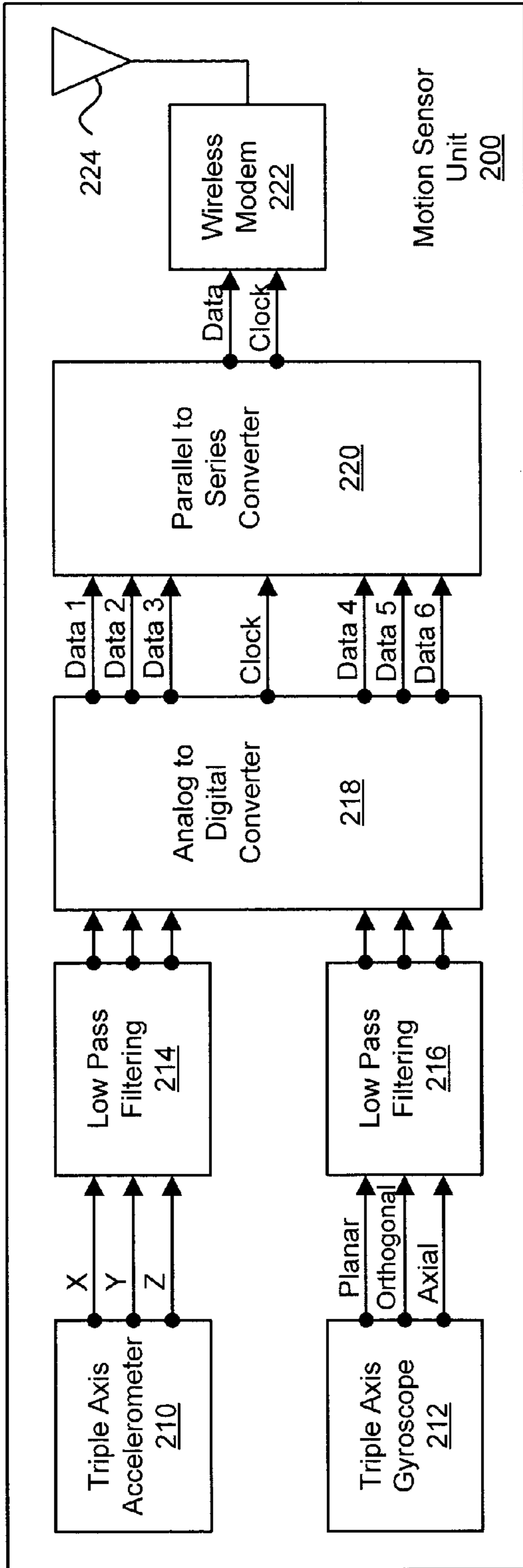


FIG. 2A

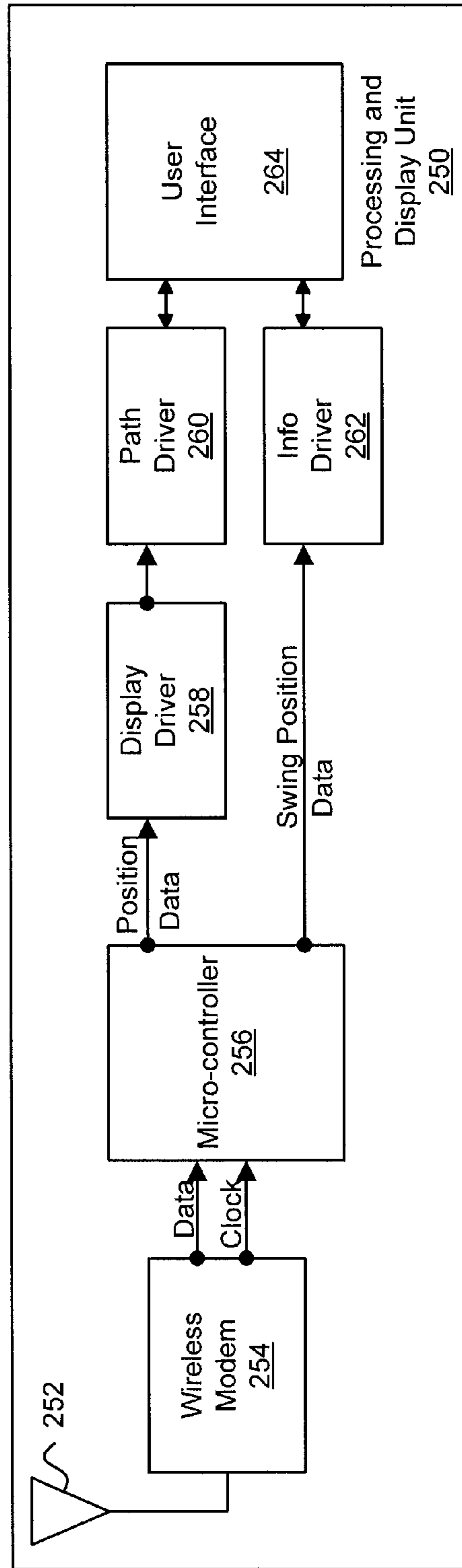


FIG. 2B

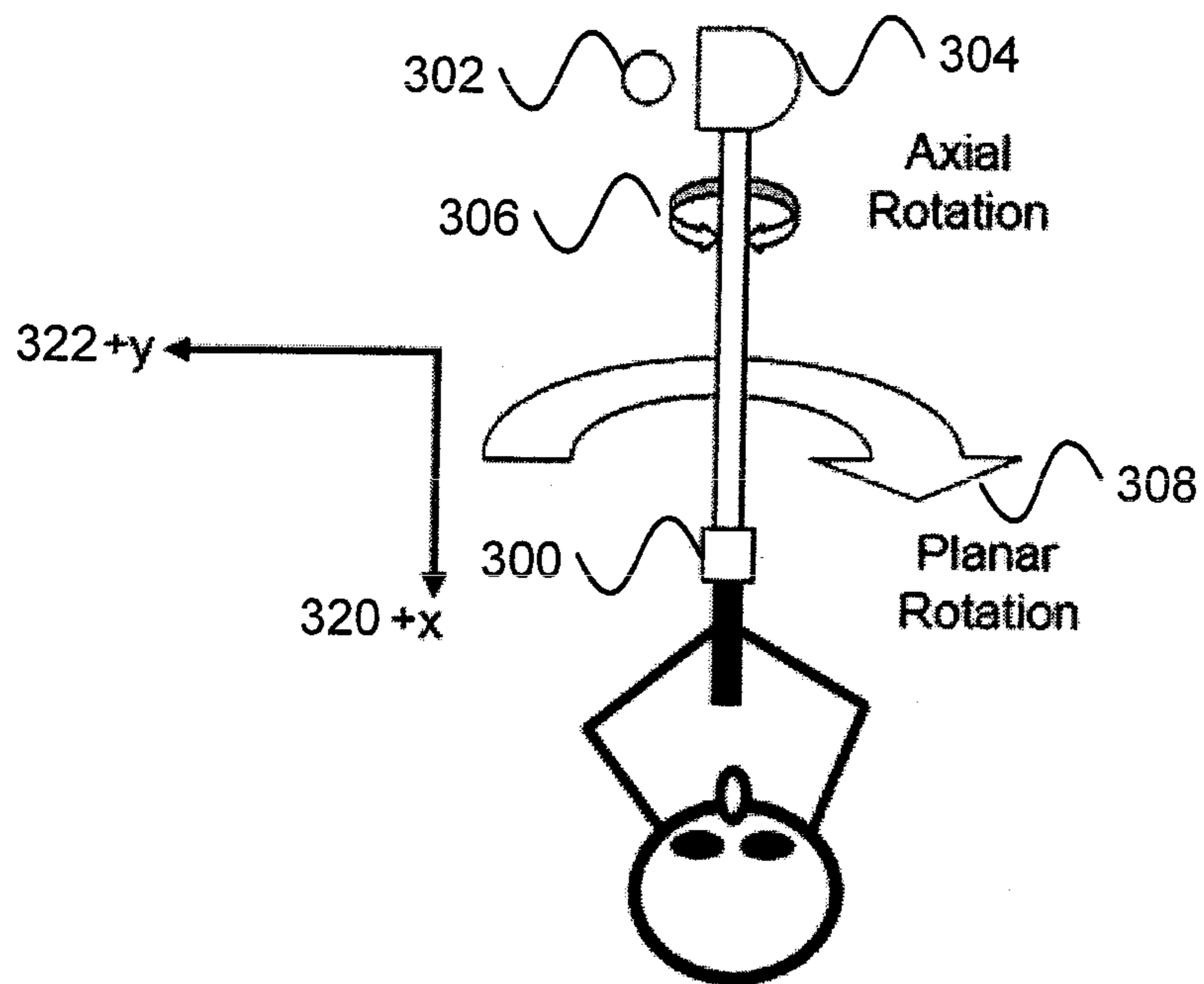


FIG. 3A

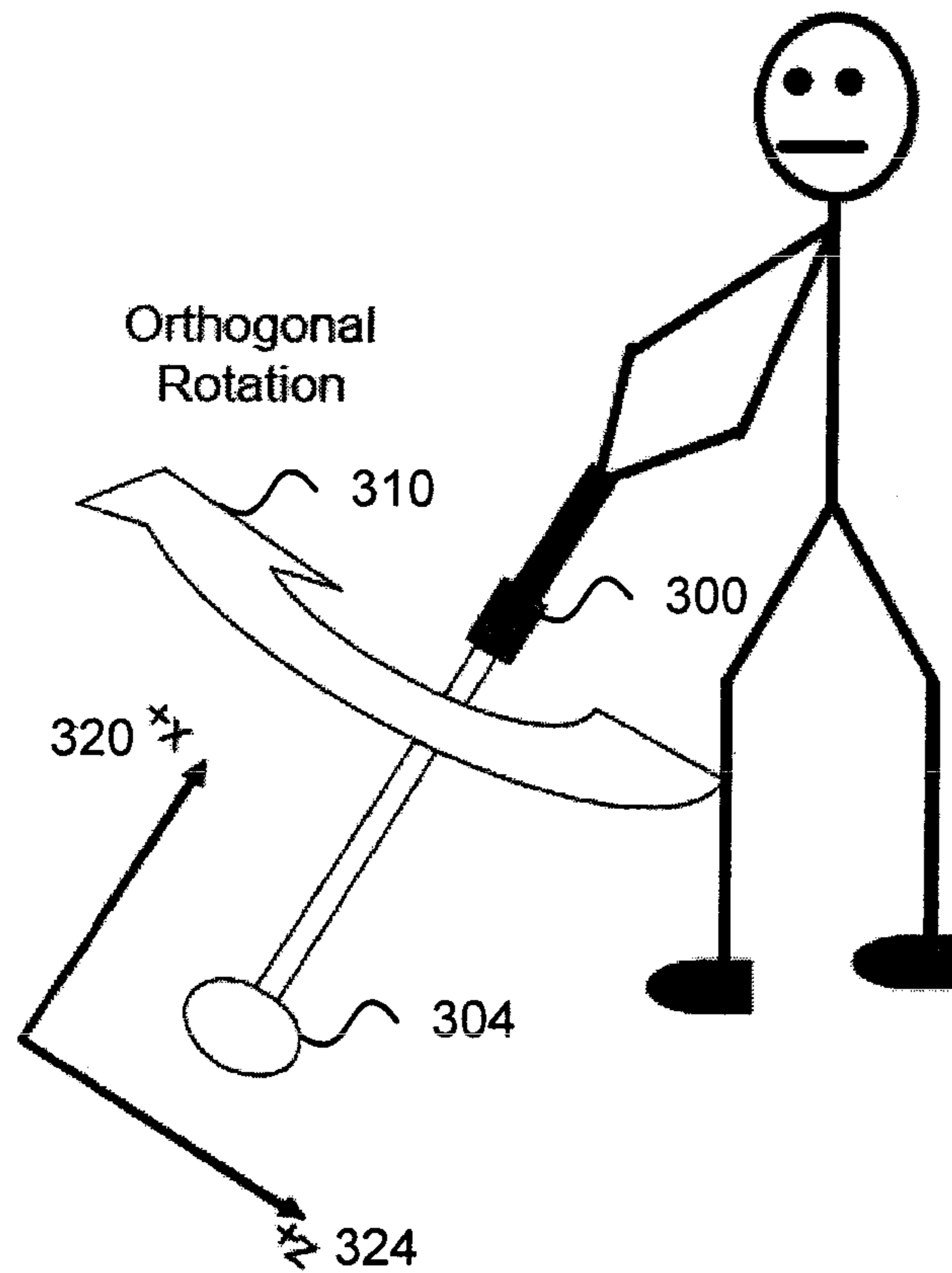


FIG. 3B

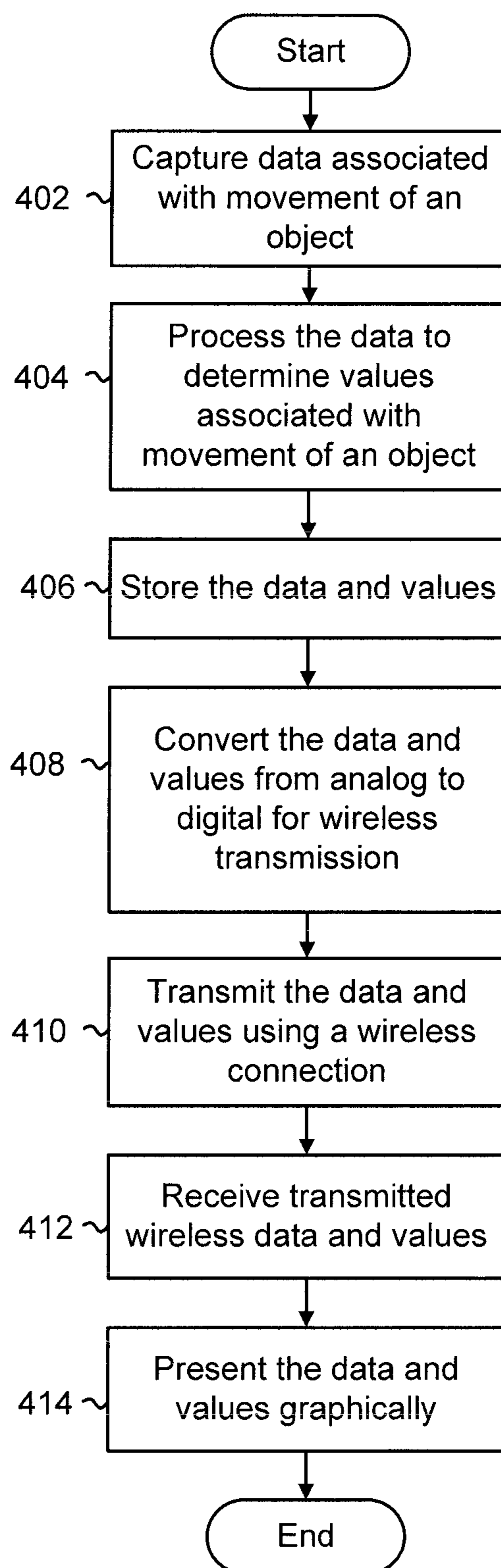


FIG. 4A



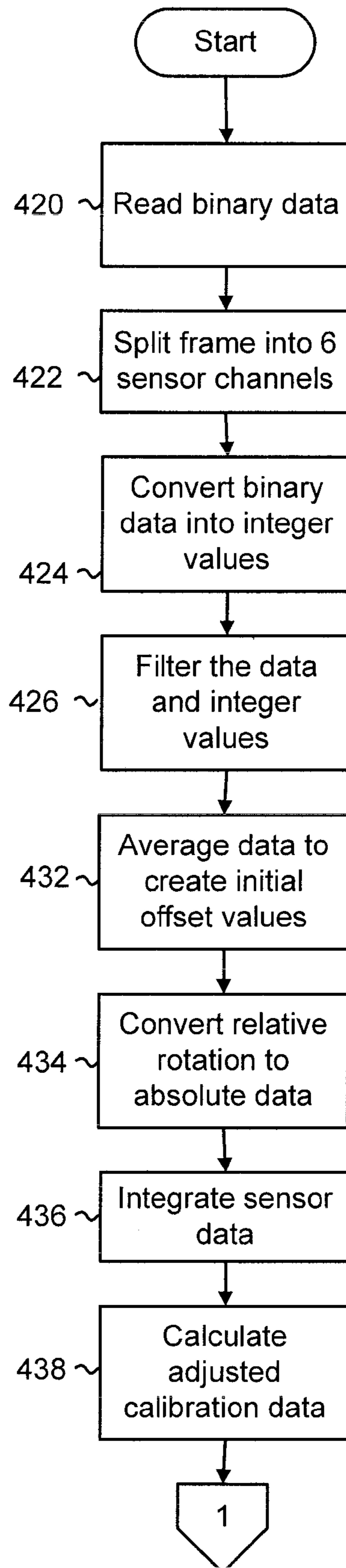


FIG. 4B

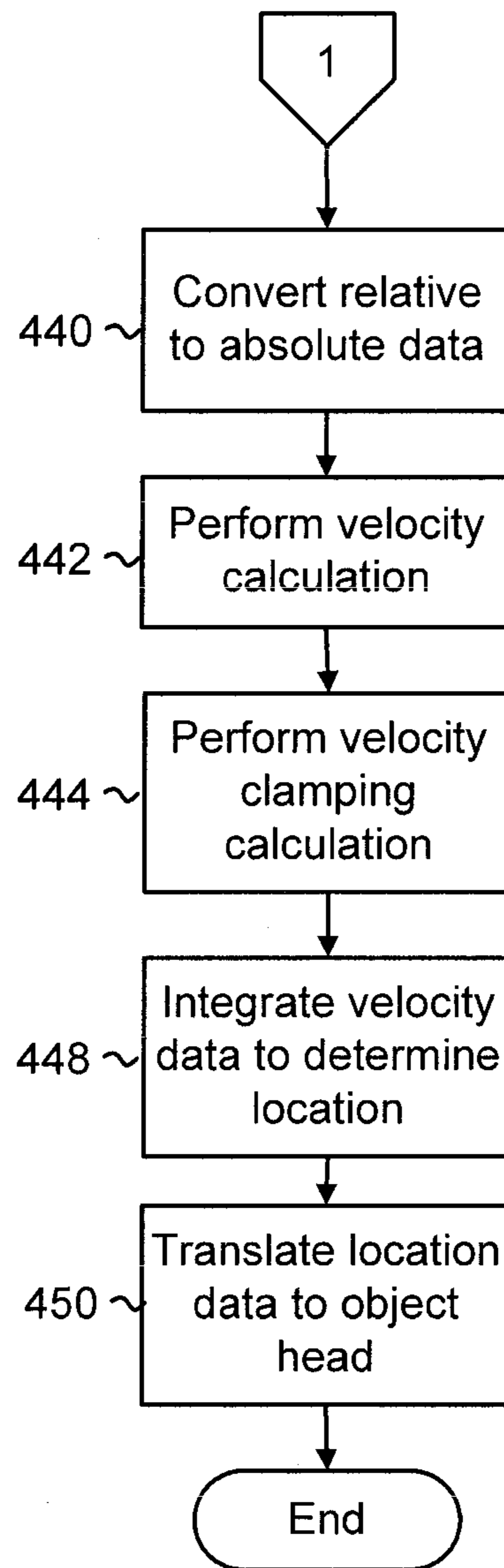


FIG. 4C

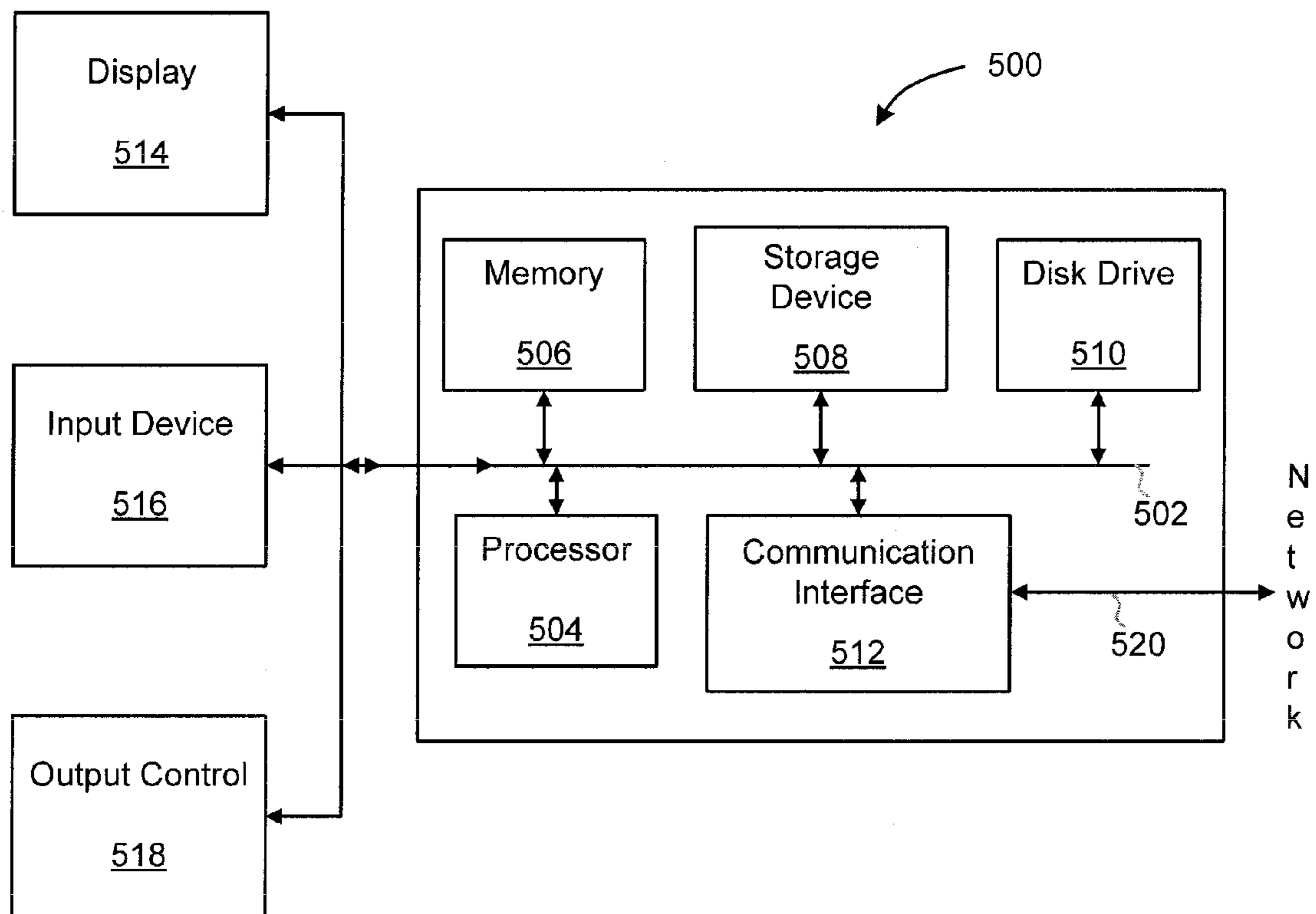


FIG. 5

## 1

## MOTION CAPTURE AND ANALYSIS

## FIELD

The present invention relates generally to computer software architecture and micro electromechanical devices and, more specifically, motion capture and analysis is described.

## BACKGROUND

The evaluation of motion in various contexts and activities is a difficult and often problematic task using conventional solutions. Conventional solutions often have bulky, cumbersome, and inaccurate implementations that can affect the actual motion being evaluated. Further, many activities in which motion of, for example, a human body is evaluated require the use of specialized equipment that is often bulky and impractical. For example, motion evaluation of a combatant soldier wearing various types of gear and weapons may require, in conventional solutions, the use of bulky or heavy motion sensors. Conventional sensors and sensory systems may be coupled to processing units using either cumbersome wiring or heavy transmission equipment that requires a fixed and not portable system, minimizing both utility and effectiveness. As another convention example, a baseball bat may have a motion sensor that is heavy and attached to the bat, which could affect the detection and evaluation of certain motions. In other activities such as golf, motion (e.g., velocity, angle of impact of a club face against a ball, trajectory, and others) is typically not measured accurately nor easily measured using conventional solutions. As many golfers are aware, the trajectory of a golf ball depends upon the forward velocity, path, and relative club face angle of a golf club at the time of impact with the golf ball. Additionally, the ability to track and display the position and the forward velocity of the golf club through a full range of swing motion is vital to developing a successful and repeatable golf swing. While conventional techniques exist to capture motion of an object, there are various problems and limitations associated with conventional motion capture and analysis apparatus and techniques.

Limitations inherent to the conventional motion capture and analysis systems generally tend to preclude the everyday golfer from utilizing or benefitting from the training benefits imparted by such a system. For example, conventional motion capture and analysis systems tend to be complex, difficult to utilize and are not user friendly. Additionally, the conventional equipment is expensive, cumbersome and is limited in usability. Conventional equipment is not readily portable and must be used at a driving range or other training facility. Conventional equipment cannot be easily transported around a golf course, often becoming cumbersome for use throughout a round of golf. Conventional equipment lacks subjectivity and relies upon a universal standard in which to compare the user's particular swing motion. Conventional equipment does not account for variation in user's physiological characteristics.

Thus, what is needed is a solution for capturing and evaluating the swing motion of a golfer without the limitations of conventional techniques and equipment.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, and like reference numerals designate like structural elements.

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FIG. 1A illustrates an exemplary system configured to implement motion capture and analysis;

FIG. 1B illustrates an alternative exemplary system;

FIG. 1C illustrates another alternative exemplary system;

FIG. 2A illustrates an exemplary application architecture configured to implement motion capture and analysis;

FIG. 2B further illustrates an exemplary application architecture configured to implement motion capture and analysis;

FIG. 3A illustrates an exemplary motion sensor unit;

FIG. 3B illustrates a further exemplary motion sensor unit;

FIG. 4A illustrates an exemplary process for motion capture and analysis;

FIG. 4B and FIG. 4C illustrate an alternative exemplary process for motion capture and analysis; and

FIG. 5 illustrates an exemplary computer system suitable to implement motion capture and analysis.

## DETAILED DESCRIPTION

Various embodiments or examples may be implemented in numerous ways, including as a system, a process, an apparatus, a user interface, or a series of program instructions on a computer readable medium such as a computer readable storage medium or a computer network where the program instructions are sent over optical, electronic, or wireless communication links. In general, operations of disclosed processes may be performed in an arbitrary order, unless otherwise provided in the claims.

A detailed description of one or more examples is provided below along with accompanying figures. The detailed description is provided in connection with such examples, but is not limited to any particular example. The scope is limited only by the claims and numerous alternatives, modifications and equivalents are encompassed. Numerous specific details are set forth in the following description in order to provide a thorough understanding. These details are provided for the purpose of example and the described techniques may be practiced according to the claims without some or all of these specific details. For clarity, technical material that is known in the technical fields related to the examples has not been described in detail to avoid unnecessarily obscuring the description.

In some examples, the described techniques may be implemented as a computer program or application ("application") or as a plug-in, module, or sub-component of another application. The described techniques may be implemented as software, hardware, firmware, circuitry, or a combination thereof. If implemented as software, the described techniques may be implemented using various types of programming, development, scripting, or formatting languages, frameworks, syntax, applications, protocols, objects, or techniques, including C, Objective C, C++, C#, Adobe® Integrated Runtime™ (Adobe® AIR™), ActionScript™, Flex™, Lingo™, Java™, Javascript™, Ajax, Perl, Python, COBOL, Fortran, ADA, XML, MXML, HTML, DHTML, XHTML, HTTP, XMPP, and others. Design, publishing, and other types of applications such as Dreamweaver®, Shockwave®, Flash®, and Fireworks® may also be used to implement the described techniques. The described techniques may be varied and are not limited to the examples or descriptions provided.

An apparatus and techniques for motion capture and analysis are described herein. By using this motion capture and analysis apparatus, a golfer may be provided a visual tool to aid in analysis and development of their golf swing. This motion capture apparatus allows a user to save their personalized best swing as a reference for future comparison. The designation of a best swing is made by the user, and is not

based upon an arbitrary universal conception of what constitutes a successful or productive swing motion. In other words, a motion capture and analysis apparatus may be used to assist the practice and perfection of a repeated dynamic motion, such as a golf swing. Various alternative implementations and modifications to the examples provided may be used and are not limited to the descriptions, dimensions, or other exemplary details provided herein.

FIG. 1A illustrates an exemplary system configured to implement motion capture and analysis. Here, system 100 includes motion sensor unit 102, display mat 104, portable display 106, display 108, terminal 110, processor 112, and database 114. In some examples, motion sensor unit 102 may be coupled, directly or indirectly, to a golf club, bat, racket, or other implement that may be used in a physical activity such as golf, baseball, tennis, or the like. Motion sensor unit 102 may include various types of devices or units (e.g., software, hardware, circuitry, or a combination thereof) for motion measurement (e.g., accelerometer, gyroscope, and others) may be used to gather data associated with the motion of a given implement that is processed using system 100. Further, using processors and wireless data communication protocols and techniques, data may be transmitted from motion sensor unit 102 to display units (e.g., portable display 106, display 108, terminal 110, or others), processor 112, or devices that may be configured to use, analyze, evaluate, transform, or perform other operations on data from motion sensor unit 102. Display 108, in some examples, may be implemented using a liquid crystal display (LCD), projection tube television, digital television, or any type of analog or digital display. As an example, display 108 may receive data for display using various types of wireless, wired, optical, acoustic, or other video data transmission protocols (e.g., S-video, high definition multimedia interface (HDMI), or others). In other examples, a wireless receiving unit (not shown) may be coupled to display 108 and used to receive data from motion sensor unit 102, processor 112, display mat 104, or other elements. In still other examples, processor 112 may be implemented as an element of a wireless receiving unit (not shown) coupled to display 108 in order to process data for generating and rendering an image or video on display 108. In further examples, a wireless receiving unit (not shown) may be referred to as a sensor pod or dongle (“dongle”) and, when coupled to display 108, process data received from motion sensor unit 102 in order to generate and render an image for display. Further, the above-described techniques may be used to provide data processing capabilities of data received from motion sensor unit 102 and rendered on display 108, terminal 110, or other types of displays not shown. Still further, data may be transmitted from motion sensor unit 102, received by a dongle (not shown), and processed, rendered, and displayed in real-time or substantially real-time on display 108. In other examples, system 100 and the above-described elements may be varied in design, function, structure, configuration, implementation, or other aspects and are not limited to the examples described.

Here, processor 112 may be used to process data provided by motion sensor unit 102 in order to generate a display on, for example, portable display unit 106 or display mat 104. As another example, processor 112 may be implemented in a separate device or in connection with motion sensor unit 102, display mat 104, portable display 106, display 108, terminal 110, or any other type of device including, for example, a television (TV), monitor, display, or other type of device. For example, motion sensor unit 102 may be coupled to a golf club (not shown) and, when the golf club is swung, data may be captured by motion sensor unit 102 and transmitted to

processor 112 using, for example, a wireless transmitter, transceiver, or the like (not shown). As another example, processor 112 may be implemented within a dongle or other type of wireless receiver coupled to display 108. When data is received by a dongle, images or video of motion captured by motion sensor unit 102 may be recorded and/or processed to display an image or video on display 108. In other examples, processor 112 may be implemented as part of display 108 without the use of a dongle or other wireless sensor pod coupled externally to display 108. In some examples, database 114 may be implemented to store and retrieve data associated with motion (e.g., swinging motion of a golf club, bat, racket, or the like) captured by motion sensor unit 102. For example, a golfer may wish to configure processor 112 to record and store data associated with a series of swings in database 114, which may be implemented using a standalone or distributed database, repository, data warehouse, storage area network (SAN), network attached storage, or other type of data storage facility using hardware and/or software. Further, once stored, data may be retrieved from database 114, which may be implemented with one, some, or none of the other elements shown in system 100. In other words, database 114 may be implemented with processor 112 with display 108. Database 114 may also be implemented with one or more of motion sensor unit 102, display mat 104, portable display unit 106, display 108, terminal 110, processor 112, or other elements (not shown). In some examples, data from motion sensor unit 102 may be transmitted to display mat 104, portable display unit 106, display 108, or terminal 110 using one or more wireless, wired, optical, acoustic, or other types of data communication links or protocols.

Once transmitted, data may be interpreted and processed by, for example, processor 112. Likewise, processor 112 may communicate data from motion sensor unit 102 to display mat 104 or other elements provided in system 100. In some examples, display mat 104 may be configured to generate, render, and display an image on its surface. Display mat 104, in some examples, may be configured for display on a horizontal, vertical, angled, or other type of surface. For example, display mat 104 be mounted on a vertical surface and used to display an image associated with a golf club, baseball bat, cricket bat, polo mallet, or others. Display mat 104 may also be configured to lie or be mounted to a horizontal surface (e.g., floor, ground, or the like) and used to present an image associated with motion under evaluation. Data for various types of motion may be evaluated and presented using the techniques described herein.

For example, motion associated with a portion of a body (e.g., human or otherwise) may be evaluated by system 100, including detecting motion using motion sensor unit 102, which is processed by processor 112 and stored in database 114 and/or presented on display mat 104, the latter of which may be implemented using various types of displays (e.g., mats, screens, upright displays, liquid crystal displays, and others without limitation). Types of motion that may be evaluated include movement by a boxer’s punching motion, a pitcher’s baseball-throwing motion, a football player’s kicking motion (e.g., a punt), running motion, combat or martial arts-related hand and foot motion, a dancer’s foot, arm, or other body motion, and others.

As another example, when data is transmitted from motion sensor unit 102, an image of a golf club head being swung may be generated on display mat 104. Further, display mat 104 may use various types of display resolution techniques and is not limited to any particular implementation. Further, display mat 104 may be implemented using a flexible LCD, active matrix, thin film transistor (TFT), or other types of

display technologies. In other example, portable display **106**, display **108**, and terminal **110** may be used to display data generated by motion sensor unit **102**, stored and retrieved from database **114**, or processed by processor **112**. Links provided by and between elements **102-112** may be implemented as unidirectional, bidirectional, or other types of data communication links. In other examples, the number, type, configuration, and topology of system **100**, motion sensor unit **102**, display mat **104**, portable display **106**, display **108**, terminal **110**, and processor **112** may be varied and are not limited to the descriptions provided.

FIG. 1B illustrates an alternative exemplary system. Here, system **120** includes display **108**, processor **112**, dongle **122**, and data connection **124**. In some examples, dongle **122** may be implemented as a wireless transceiver to receive and/or send data from processor **112** over data connection **124**, which may be implemented using wired, wireless, optical, acoustic, or other types of data communication protocols. In other examples, dongle **122** may be implemented using a wired data connection (not shown) in order to receive data for generating, rendering, and displaying an image on display **108**. In still other examples, processor **112** may be implemented as part of dongle **122**. Further, other elements (e.g., one or more of motion sensor unit **102**, processor **112**, database **114**, or others) may be implemented or integrated with dongle **122**. Still further, system **120** and the above-described elements may be varied in implementation, function, structure, or other aspects and are not limited to the examples provided above.

FIG. 1C illustrates another alternative exemplary system. Here, system **130** includes motion sensor unit **102**, display mat **104**, display **108**, processor **112**, database **114**, dongle **122**, and data connection **124**, which may be implemented as described above or differently. Further, application **132** may include motion sensor unit **102**, display mat **104**, processor **112**, and database **114**, which may be implemented as described above or differently. Further, application **132** may be implemented using a standalone, distributed, or other type of application architecture or topology. Alternatively one or more elements (e.g., motion sensor unit **102**, display mat **104**, processor **112**, database **114**, or others) of application **132** may be implemented apart from or as part of dongle **122** or display **108**. In other examples, system **130** and the above-described elements may be varied in implementation, function, or structure and are not limited to the descriptions provided.

FIG. 2A illustrates an exemplary application architecture configured to implement motion capture and analysis. Here, motion sensor unit **200** includes triple axis accelerometer **210**, triple axis gyroscope **212**, low pass filtering **214**, low pass filtering **216**, analog to digital converter **218**, parallel to series converter **220**, wireless modem **222** and wireless transceiver **224**. In some examples, motion sensor unit **200** may include a micro-controller (not shown) similar to micro-controller **256** (described below in connection with FIG. 2B).

In some examples, motion sensor unit **200** may be detachably coupled to an object (e.g., golf club, tennis racket, baseball bat, softball bat, hockey stick, other sporting equipment, or others). Motion sensor unit **200** may be various sizes and shapes to accommodate a static and secure attachment to the various shapes and sizes of the detachably coupled object. Motion sensor unit **200** may have an adjustable attachment mechanism to enable one unit to accommodate various shapes and sizes of attached objects. Motion sensor unit **200** may be lightweight and easily portable. Motion sensor unit **200** may be easily attached or detached from the object by the user, without the need for specialized tools or accessories. In

other examples, motion sensor unit **200** and the above-described elements may be implemented differently and are not limited to the descriptions provided.

In some examples, a power supply (not shown) such as a battery or external AC/DC converter may be coupled to motion sensor unit **200**. Power supplies may be implemented as rechargeable, non-rechargeable, portable, or disposable batteries. In other examples, a battery (not shown) may be implemented as part of motion sensor unit **200**, supplying power to motion sensor unit **200** and its associated components. In still other examples, a power source may be implemented as another attachment to motion sensor unit **200**.

In some examples, triple axis accelerometer **210** and triple axis gyroscope **212** may be configured to measure movement of an object (e.g., golf club, tennis racket, baseball bat, softball bat, hockey stick, other sporting equipment, or others). In some examples, triple axis accelerometer **210** and triple axis gyroscope **212** may be a micro electromechanical system (MEMS) device. In other examples, triple axis accelerometer **210** and triple axis gyroscope **212** may be an analog or digital device. In some examples, triple axis accelerometer **210** may be configured to measure the acceleration of the object along the x-axis, y-axis and z-axis and triple axis gyroscope **212** may be configured to measure the rotational movement of the object along the planar, orthogonal and axial directions. In other examples, triple axis accelerometer **210** and triple axis gyroscope **212** may be configured differently and are not limited to the descriptions provided.

Here, triple axis accelerometer **210** communicates the data signal to low pass filtering **214** and triple axis gyroscope **212** communicates the data signal to low pass filtering **216**. Further, low pass filtering **214** and low pass filtering **216** communicate the data signal to analog to digital converter **218**. In some examples, analog to digital converter **218** may be configured to convert the data from an analog signal to a digital signal. Here, analog to digital converter **218** communicates the data signal to parallel to series converter **220**. In some examples, parallel to series converter **220** is configured to convert the data signal from a parallel electrical signal to a series electrical signal.

Here, parallel to series converter **220** communicates the data signal to wireless modem **222**. Wireless modem **222** is coupled to wireless transceiver **224** for sending and receiving signals (e.g., RF) between motion sensor unit **200** and display unit (described below in connection with FIG. 2B). In some examples, wireless transceiver **224** may be configured to send and receive communication signals using various wireless formats (e.g., ZigBee (i.e., IEEE 802.15.4 data communication protocol/standard/specification), radio frequency (RF) waves, IEEE 802.11, Bluetooth, UHF, or others).

FIG. 2B further illustrates an exemplary application architecture configured to implement motion capture and analysis. Here, processing and display unit **250** includes wireless modem **254**, wireless transceiver **252**, micro-controller **256**, display driver **258**, path driver **260**, info driver **262** and user interface **264**. In some examples, processing and display unit **250** may be a remote device or system (e.g., display mat, portable display device, television monitor, computer, server, video recorder, or others) configured to present or display visual, graphical or numerical data measured by the motion sensor unit (described above in connection with FIG. 2A) and values associated with object movement, which are calculated using the measured data. In some examples, processing and display unit **250** may be configured to save the graphic and numerical data and values associated with a user selected reference point (i.e., "best swing") for comparison with subsequent iterations of the object movement. In some examples,

processing and display unit **250** may be configured to provide an acoustic indication or response. Processing and display unit **250** may be configured with a memory device (not shown here). The memory device may be a permanent or removable memory card or hard drive.

In some examples, processing and display unit **250** presents various parameters associated with the motion of an object such as measured data (e.g., three dimensional acceleration, three dimensional rotational acceleration, maximum acceleration, or others) or calculated values (e.g., three dimensional velocity, three dimensional rotational velocity, location coordinates, maximum velocity, impact velocity, relative angle of object at point of impact, or others). Still further, processing and display unit **250** may be configured to graphically present a directional path representing the actual movement of an object and graphically indicate various significant points of reference (e.g., point of maximum velocity, or others) along the object's path of movement. In other examples, processing and display unit **250** may be configured to present or display any number of different visual, graphical or numerical parameters associated with the movement of an object and are not limited to the descriptions provided.

In some examples, processing and display unit **250** may be a display mat for use on a horizontal and flat surface, which display mat may be various sizes, shapes or dimensions. A display mat (e.g., display mat **104** (FIG. 1A)) may be configured such that the user stands on the mat while moving the object, or stands adjacent to the mat while moving the object. A display mat may also be made of a material that is durable, impact resistant and able to sustain the weight of a person. In some examples, a display mat may be made of a material that is easily rolled up and lightweight for easy portability. As an example, a display mat may be made of an array of surface mounted light emitting devices (LEDs). The display mat may be configured to present or display any or all of the visual, graphic or numerical parameters discussed above. In other examples, processing and display unit **250** may be implemented differently and is not limited to the descriptions provided.

In other examples, processing and display unit **250** may be a portable display device for handheld use. In some examples, a portable display device may be small, lightweight and easily transported by the user. In other examples, a portable display device may be various sizes, shapes or dimensions. A portable display device may also be configured to present or display any or all of the visual, graphic or numerical parameters discussed above. In other examples, processing and display unit **250** as a portable display device may be implemented differently and is not limited to the descriptions provided.

In some examples, a power supply (not shown) such as a battery or external AC/DC converter may be coupled to processing and display unit **250**. Power supplies may be implemented as rechargeable, non-rechargeable, portable, or disposable batteries. In other examples, a battery (not shown) may be implemented as part of processing and display unit **250**, supplying power to processing and display unit **250** and its associated components. In still other examples, a power source may be implemented as another attachment to processing and display unit **250**.

Here, wireless modem **254** is coupled to wireless transceiver **252** for sending and receiving signals (e.g., RF) between processing and display unit **250** and motion sensor unit **200** (described above in connection with FIG. 2A). In some examples, wireless transceiver **252** may be configured to send and receive communication signals using various wireless formats (e.g., ZigBee, RF waves, IEEE 802.11, Bluetooth, UHF, or others).

Here, wireless modem **254** communicates the data signal to micro-controller **256**. In some examples, micro-controller **256** is configured to process the measured data captured by motion sensor unit **200** (described above in connection with FIG. 2A). Micro-controller **256** may calculate values associated with movement of an object (e.g., three dimensional velocity, three dimensional rotational velocity, location coordinates, maximum velocity, impact velocity, relative angle of object at point of impact, or others) using the movement data captured by motion sensor unit **200** (described above in connection with FIG. 2A).

Here, micro-controller **256** communicates a position data signal to display driver **258** and swing position data to info driver **262**. Here further, display driver **258** communicates the position data to path driver **260**. Finally, path driver **260** and info driver **262** communicate the position and swing position data to and from user interface **264**.

In some examples, user interface **264** may be configured to include user controls which allow user configuration of the system. User interface **264** controls may include various input mechanism and allow the user to save a selected reference point (i.e., "best swing") or select the desired display parameters. In some examples, user interface **264** may be configured to include an acoustic signal to provide an auditory indication. In other examples, user interface **264** may be configured differently and is not limited to the descriptions provided. Still further, processing and display unit **250** and the above-described elements may be implemented differently and is not limited to the descriptions or examples provided above.

FIG. 3A illustrates an exemplary motion sensor unit. Here, a top view of an exemplary user of the motion sensor unit is shown. In this example, motion sensor unit **300**, impact object **302**, movement object **304**, axial rotation **306**, planar rotation **308**, x-axis **320** and y axis **322** are shown. Motion sensor unit **300** may be configured and implemented as described above as motion sensor unit **200** (described above in connection with FIG. 2A). As shown here, motion sensor unit **300** may be used to measure and capture axial rotation **306**, planar rotation **308**, x-axis acceleration along x-axis **320** and y-axis acceleration along y-axis **322**. In other examples, motion sensor unit **300** may be configured to measure and capture other parameters associated with movement of an object and is not limited by the descriptions provided.

As shown here, motion sensor **300** is coupled to movement object **304**, as shown here as a golf club. In other examples, movement object **304** may be a tennis racket, baseball bat, softball bat, hockey stick, other sporting equipment, or other moveable object. As shown here, movement object **304** is intended to make dynamic contact with impact object **302**, as shown here as a golf ball. In other examples, impact object **302** may be a baseball, softball, hockey puck, or other moving object. In other examples, movement object **304** and impact object **302** may be different and are not limited to the descriptions provided.

FIG. 3B illustrates a further exemplary motion sensor unit. Here, a side view of an exemplary user of the motion sensor unit is shown. In this example, motion sensor unit **300**, movement object **304**, orthogonal rotation **310**, x-axis **320** and z-axis **324** are shown. Motion sensor unit **300** may be configured and implemented as described above as motion sensor unit **200** (described above in connection with FIG. 2A). As shown here, motion sensor unit **300** may be used to measure and capture orthogonal rotation **310**, x-axis acceleration along x-axis **320** and z-axis acceleration along z-axis **324**. In other examples, motion sensor unit **300** may be configured to

measure and capture other parameters associated with movement of an object and is not limited by the descriptions provided.

As shown here, motion sensor **300** is coupled to movement object **304**, as shown here as a golf club. In other examples, movement object **304** may be a tennis racket, baseball bat, softball bat, hockey stick, other sporting equipment, or other moveable object. As shown here, movement object **304** is intended to make dynamic contact with impact object (not shown). In other examples, movement object **304** may be different and is not limited to the descriptions provided.

FIG. **4A** illustrates an exemplary process for motion capture and analysis. In some examples, data associated with movement of an object may be captured (**402**). The data may be processed to determine values associated with movement of the object (**404**). The data and the values may be stored (**406**). The data and values may be converted from analog to digital for a wireless transmission (**408**). The data and the values may be transmitted using a wireless connection (**410**). Once transmitted, data and values may be received using, for example, a wireless modem (FIG. **2B**) configured to modulate or demodulate transmitted data for processing and presentation on a display (e.g., display **108** (FIGS. **1A-1C**) (**412**). The data and values may be presented graphically (**414**). The above-described process may be varied in function, processes and performed in any arbitrary order and is not limited to the examples shown and described.

FIG. **4B** and FIG. **4C** illustrate an alternative exemplary process for motion capture and analysis. In some examples, binary data may be read (**420**). The frame may be split into **6** sensor channels (**422**). The binary data may be converted into integer values (**424**). The data and integer values may be filtered (**426**). Optionally, a “swing started” calculation may be performed (not shown) to determine when a swinging motion begins. A “swing started” calculation or determination may be performed, in some examples, after filtering data and integer values. Further, an optional operation for creating a lapsed time index may also be created (not shown). The data may be averaged to create initial offset values (**432**). Relative rotation may be converted to absolute data (**434**). The sensor data may be integrated (**436**). The adjusted calibration data may be calculated (**438**). Relative data may be converted to absolute data (**440**). A velocity calculation may be performed (**442**). A velocity clamping calculation may be performed (**444**). Optionally, a “swing end” calculation may be performed to determine when a swing motion ends or terminates (**446**). Velocity data may be integrated to determine location (**448**). Location data may be translated to object head (**450**). The above-described process may be varied in function, processes and performed in any arbitrary order and is not limited to the examples shown and described.

FIG. **5** illustrates an exemplary computer system suitable to implement motion capture and analysis. In some examples, computer system **500** may be used to implement computer programs, applications, methods, processes, or other software to perform the above-described techniques. Computer system **500** includes a bus **502** or other communication mechanism for communicating information, which interconnects subsystems and devices, such as processor **504**, system memory **506** (e.g., RAM), storage device **508** (e.g., ROM), disk drive **510** (e.g., magnetic or optical), communication interface **512** (e.g., modem or Ethernet card), display **514** (e.g., CRT or LCD), input device **516** (e.g., keyboard), and output control **518**.

According to some examples, computer system **500** performs specific operations by processor **504** executing one or more sequences of one or more instructions stored in system

memory **506**. Such instructions may be read into system memory **506** from another computer readable medium, such as static storage device **508** or disk drive **510**. In some examples, hard-wired circuitry may be used in place of or in combination with software instructions for implementation.

The term “computer readable medium” refers to any tangible medium that participates in providing instructions to processor **504** for execution. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media. Non-volatile media includes, for example, optical or magnetic disks, such as disk drive **510**. Volatile media includes dynamic memory, such as system memory **506**.

Common forms of computer readable media includes, for example, floppy disk, flexible disk, hard disk, magnetic tape, any other magnetic medium, CD-ROM, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, RAM, PROM, EPROM, FLASH-EPROM, any other memory chip or cartridge, or any other medium from which a computer can read.

Instructions may further be transmitted or received using a transmission medium. The term “transmission medium” may include any tangible or intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine, and includes digital or analog communications signals or other intangible medium to facilitate communication of such instructions. Transmission media includes coaxial cables, copper wire, and fiber optics, including wires that comprise bus **502** for transmitting a computer data signal.

In some examples, execution of the sequences of instructions may be performed by a single computer system **500**. According to some examples, two or more computer systems **500** coupled by communication link **520** (e.g., LAN, PSTN, or wireless network) may perform the sequence of instructions in coordination with one another. Computer system **500** may transmit and receive messages, data, and instructions, including program, i.e., application code, through communication link **520** and communication interface **512**. Received program code may be executed by processor **504** as it is received, and/or stored in disk drive **510**, or other non-volatile storage for later execution.

Although the foregoing examples have been described in some detail for purposes of clarity of understanding, the invention is not limited to the details provided. There are many alternative ways of implementing the invention. The disclosed examples are illustrative and not restrictive.

What is claimed:

1. A system, comprising:

a non-wearable motion sensor unit configured to be adjustably coupled to, but not mechanically integrated with, an outer surface at a first location on an object using an adjustable attachment mechanism, the object being used in a physical activity, the non-wearable motion sensor unit being further configured to be removed from the object and adjustably coupled to, but not mechanically integrated with, another outer surface of another object using the adjustable attachment mechanism and to capture data associated with movement of the object, to process the data to determine one or more values, to store the data and the one or more values, to translate the values to correspond to a second location on the object located away from the first location, and to convert an analog signal to a digital signal comprising the data and the one or more values; and

a display unit configured to receive the data from the non-wearable motion sensor unit, the data being transmitted using through the wireless transmission, to process the



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data to determine one or more values, to store the data, and to graphically present the data and the one or more values.

2. The system of claim 1, wherein the data comprises acceleration data associated with the object.

3. The system of claim 1, wherein the data comprises angular momentum data associated with the object.

4. The system of claim 1, wherein the one or more values indicate a maximum velocity associated with the object.

5. The system of claim 1, wherein the one or more values indicate a graphical path associated with the object.

6. The system of claim 1, wherein the one or more values indicate a velocity associated with the object at a time when the object impacts another object.

7. The system of claim 1, wherein the one or more values indicate an angle associated with the object at a time when the object impacts another object.

8. The system of claim 1, wherein the one or more values indicate a trajectory associated with the object adheres to a fixed plane.

9. The system of claim 1, further comprising a control unit coupled to the non-wearable motion sensor unit, the control unit being configured to receive input.

10. The system of claim 1, further comprising a graphic indicator unit coupled to the non-wearable motion sensor unit, the graphic indicator unit being configured to present the data and the one or more values.

11. The system of claim 1, wherein the display unit is configured to graphically present the data and the one or more values as an image.

12. The system of claim 1, wherein the display unit is configured to graphically present an image comprising the data and the one or more values.

13. The system of claim 1, wherein the non-wearable motion sensor unit is detachably and adjustably coupled to the object.

14. The system of claim 1, wherein the display unit is a display mat.

15. The system of claim 1, wherein the object is a golf club.

16. The system of claim 1, wherein the object is a baseball bat.

17. The system of claim 1, wherein the object is a tennis racket.

18. The system of claim 1, wherein the object is a hockey stick.

19. The system of claim 1, wherein the object is a fishing pole.

20. The system of claim 1, wherein the object is a racquetball racquet.

21. The system of claim 1, wherein the object is a squash racquet.

22. A system, comprising:

a non-wearable motion sensor unit configured to be adjustably coupled to, but not mechanically integrated with, an outer surface at a first location on an object using an adjustable attachment mechanism, the object being used in a physical activity, the non-wearable motion sensor unit being further configured to be removed from the object and adjustably coupled to, but not mechanically integrated with, another outer surface of another object using the adjustable attachment mechanism and comprising a motion measurement unit configured to capture data associated with movement of the object;

a processor configured to process the data to determine one or more values associated with movement of the object,

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and to translate the values to correspond to a second location on the object located away from the first location;

a wireless transmitter being coupled to the non-wearable motion sensor unit, the wireless transmitter being configured to transmit the data; and

a display unit comprising a display and a wireless transceiver, the wireless transceiver being coupled to the display unit and configured to send and receive the data from the non-wearable motion sensor unit and another processor configured to process the data and generate an image based on the data.

23. A system, comprising:

a non-wearable motion sensor unit configured to be adjustably coupled to, but not mechanically integrated with, an outer surface at a first location on an object using an adjustable attachment mechanism, the object being used in a physical activity, the non-wearable motion sensor unit being further configured to be removed from the object and adjustably coupled to, but not mechanically integrated with, another outer surface of another object using the adjustable attachment mechanism, the motion sensor unit comprising a three-dimensional accelerometer and a gyroscope configured to capture data associated with movement of the object, a processor configured to process the data to determine one or more values associated with movement of the first location on the object and to translate the values to correspond to a second location on the object located away from the first location, and a wireless transmitter coupled to the non-wearable motion sensor unit, the wireless transmitter being configured to transmit and receive the data;

a display unit comprising a graphic display, a wireless transceiver coupled to the display unit, the wireless transceiver being configured to send and receive the data from the non-wearable motion sensor unit, and another processor configured to process the data and generate an image to be presented on the graphic display;

a portable handheld display unit comprising another graphic display, another wireless transceiver being coupled to the portable display unit, the another wireless transceiver being configured to send and receive the data from the non-wearable motion sensor unit; and

a further processor configured to process the data and generate another image to be presented on the another graphic display.

24. A method, comprising:

capturing data associated with movement of an object, the data corresponding to a first location on the object and being captured by a non-wearable motion sensor unit adjustably coupled to, but not mechanically integrated with, an outer surface of the object at the first location using an adjustable attachment mechanism the object being used in a physical activity, the non-wearable motion sensor unit being further configured to be removed from the object and adjustably coupled to, but not mechanically integrated with, another outer surface of another object using the adjustable attachment mechanism;

processing the data to determine one or more values associated with the movement of the object;

translating the values to correspond to a second location on the object located away from the first location;

storing the data and the one or more values;

converting an analog signal to a digital signal, the digital signal comprising the data and the one or more values;

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transmitting the digital signal using a wireless connection established between a wireless transmitter and a wireless transceiver; and presenting the data and the one or more values graphically.

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